Seismic constraints on internal structure of A and F-type stars

All information about stars that astronomers receive is carried by electromagnetic radiation which is registered by various detectors. Recent enormous progress in instrumental astronomy allows us to reach the more and more distant corners of the Universe. We build larger and larger telescopes and use more and more advanced observational techniques. However, even the largest telescopes and most sophisticated methods of observations will not allow us to look inside a star. The only witnesses of what is happening inside stellar interior are neutrinos, very elusive particles that we cannot register from stars other than our Sun.

The only method which can uncover the secrets thus hidden behind substantial barriers is *asteroseismology*. This relatively new branch of astrophysics makes use of stellar pulsations, a phenomenon occurring in stars of different masses and at various evolutionary stages. The pulsations are caused by the propagation of acoustic or buoyance waves inside stellar interiors and the observational evidence is periodic variability of the stellar brightness, radial velocity or shape of spectral lines. The values of the frequencies of these changes are extracted from time-series analysis. Each eigenfrequency corresponds to different pulsational mode and the types of excited modes are uniquely determined by the structure and conditions inside the star. By fitting the theoretical values of the frequencies to the observed ones, one can obtain stringent constraints on the physical processes that determine the internal structure, evolution and ultimate fate of the star. Thus, *asteroseismology* is the stellar analogue of seismic probing of the Earth's structure by geophysicists.

In this project we focus on the issue "What physics can we learn from oscillations of δ Scuti stars?" δ Scuti stars are pulsating variables with masses of about 1.5 – 3.0 times that of the Sun. Most of them are in the main-sequence phase of evolution, i.e., they burn hydrogen in their cores, but there are δ Sct stars that have already completed central hydrogen burning and are in the hydrogen-shell burning stage and expanding to red giants. There are also very young δ Sct variables before hydrogen ignition in the core.

The project aims at obtaining constraints on physical processes that determine the internal structure, evolution and final fate of stars. In particular we focus on mixing of chemical elements, internal rotation, subphotospheric convection as well as on microphysics data, i.e., stellar opacities. We will estimate the efficiency of the convective energy transport and compare how this efficiency changes from star to star. Determination of the seismic corrections to the mean opacity profile will answer the question whether the same opacity modifications as in case of the hotter pulsators we studied are needed to account for all pulsational properties derived from observations. Our first results have already shown that the opacity enhancement at the depth corresponding to temperature of about 120 000 K is indispensable for the δ Sct stars in which both acoustic and buoyancy modes are excited. The test of the stellar opacity is vital for all branches of astrophysics because the opacities determine the transport of energy through matter. The other important factor guiding stellar evolution is rotation which changes the structure of the star and, additionally, it mixes chemical elements. All kinds of rotationally induced mixing are described by some free parameters and constraining them is of very high importance.

The novelty of the project is to find simultaneously seismic corrections to the model, rotational profile and opacities. For the first time, modifications of the mean opacity profile will be derived from seismic studies of stars with masses of about 2 $M_{\odot}$.

The results of our complex seismic studies of δ Scuti stars will be vital for better understanding and further improvements in computations of stellar structure and evolution, and can be implemented into the modern numerical codes.